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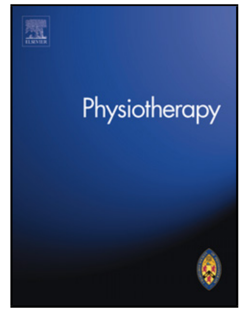

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Do isometric pull-down exercises increase the acromio-humeral distance?

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Abstract

Objectives To evaluate the effect of isometric shoulder extension in 90° shoulder flexion on the acromio-humeral distance, to establish the force required to achieve a clinically important increase in the acromio-humeral distance, and to investigate the practicality and reliability of real-time ultrasound measurement of the acromio-humeral distance in 90° shoulder forward flexion.

Design Prospective single-group intervention.

Setting King's College London, Guy's Campus.

Participants Twenty healthy volunteers [five males and 15 females (40 shoulders)] with a mean age of 32 (standard deviation 10, range 19 to 55) years were recruited from the faculty and staff at King's College London.

Interventions The acromio-humeral distance in asymptomatic participants was measured using real-time ultrasound in the neutral position at rest, at 90° shoulder flexion at rest, and while performing an isometric pull-down exercise at 100%, 50%, 30% and 10% maximal voluntary isometric contraction.

Main outcome measures Real-time ultrasound measures of the acromio-humeral distance.

Results Of the 20 participants, 38 shoulders were imaged. In 90° shoulder flexion, pull-down exercises at all levels of force increased the acromio-humeral distance compared with no pull-down (*P*<0.05), but this was only clinically significant in males. Measures had excellent short-term intra-operator reliability.

Conclusions Isometric pull-down exercises lead to an increase in the acromio-humeral distance in asymptomatic males that may be clinically important, and therefore may be an appropriate exercise for patients with shoulder pathology. Ultrasound measurement of the acromio-humeral distance in 90° shoulder flexion is practical and reliable.

Keywords: Shoulder; Ultrasound; Subacromial space; Rotator cuff; Impingement; Pull-down

<A>Introduction

Shoulder pain is the third most prevalent musculoskeletal disorder in primary care [1]. Between 30% and 70% of shoulder pain is attributed to pathology of structures within the subacromial space [2]. The subacromial space lies between the acromion and the humeral head, and the smallest distance between them is known as the ‘acromio-humeral distance’ [3]. The acromio-humeral distance varies with shoulder position, is greatest at rest in the neutral position (10–15 mm), and is least between 30° and 90° abduction in the scapular plane and at 90° flexion in the sagittal plane [4–6].

Subacromial pathology is associated with a reduction in the acromio-humeral distance. Patients with rotator cuff tears and rotator cuff dysfunctions had 1.9 mm and 2.1 mm smaller acromio-humeral distances, respectively, compared with healthy subjects, suggesting that a change of approximately 2 mm may be clinically important [4,7]. A acromio-humeral distance $\leq$7 mm at rest in the neutral position indicates a rotator cuff tear with 75% specificity, and a distance <6 mm may indicate a total rupture [8]. This reduction in the acromio-humeral distance in shoulder pain and pathology is thought to be due to superior migration of the humeral head towards the acromial arch, and is frequently associated with muscle dysfunction in the shoulder region such that there is a reduction of scapular upward rotation, posterior tilt and external rotation [4,9].

Studies have examined the effect of muscle contraction on the acromio-humeral distance in varying shoulder positions, in part to evaluate the theoretical suitability of exercises in the management of shoulder pathology. Resisting shoulder abduction leads to a reduction in the acromio-humeral distance, particularly at 60° and 75° abduction [6]. This may be due to increased force of the deltoid muscle leading to greater superior humeral migration. Isometric adduction in varying degrees of shoulder abduction results in an increase in the acromio-humeral distance compared with abduction, and it is hypothesised that this was due to inferior and anterior translation of the humeral head associated with pectoralis major, latissimus dorsi and teres major activity [10]; however, the relative individual contribution of these muscles has yet to be investigated. White *et al.* [3] showed a non-significant trend for the acromio-humeral distance to reduce with resisted isometric external rotation compared with internal rotation or no contraction at both 30° and 45° shoulder abduction [3]. In the neutral position, there were no changes in the acromio-humeral distance with either internal or external rotation compared with rest [3].

As the greatest reduction in the acromio-humeral distance occurs at 90° of shoulder forward flexion [5], an important functional position, increasing the acromio-humeral distance in this position may benefit patients with subacromial pathology. A pull-down exercise from 90° shoulder flexion has been advocated in the treatment of subacromial pain [11], as the pectoralis major, latissimus dorsi and teres major are theorised to depress the humeral head and thus increase the acromio-humeral distance [10].

The acromio-humeral distance has been measured using x-ray, magnetic resonance imaging, computed tomography and ultrasonography [4,8,12–14]. Real-time ultrasound imaging is non-invasive and does not use radiation. Ultrasound measures of the acromio-humeral distance have high validity compared with x-ray [4,15], and excellent intra- and inter-rater reliability [16]. To the authors' knowledge, no reports on the use of ultrasound to measure the acromio-humeral distance in 90° flexion have been published to date, and it is unclear if this is a practical or reliable technique.

Therefore, the primary aims of this study were to examine the acromio-humeral distance in 90° flexion with and without load into isometric extension, and to examine the reliability and practicality of shoulder real-time ultrasonography, not reported previously in this important functional position. It was hypothesised that an isometric extension contraction in 90° of forward flexion would increase the acromio-humeral distance. A secondary aim of this study was to determine the percentage of an individual's maximal force required to produce a clinically important increase in the acromio-humeral distance.

<A>Methods

<B>Participants

Following approval by the King's College London Research Ethics Committee, participants were recruited from the college faculty via e-mail and posters. Exclusion criteria were: age <18 years; inadequate command of English; shoulder area pain within last 6 months; any previous medically diagnosed shoulder pathology; and systemic illness that might result in shoulder pain or muscle weakness. All participants gave written, informed consent. An internal pilot study of five subjects (10 shoulders) found a mean change in the acromio-humeral distance of 1.5 [standard deviation (SD) 2.7] mm; therefore, 28 shoulders were required for a power of 80% with P=0.05. Age, sex, height, weight, arm dominance and relevant medical history were recorded.

<B>Materials

Acromio-humeral distance was measured using the Aloka 55D-900 (Aloka Co Ltd, Tokyo, Japan) ultrasound scanner with a 7.5-MHz linear transducer in B mode. The scanner was calibrated before data collection by comparison with metal phantoms of known dimensions. A force transducer (self-built) and PowerLab 4/25T software (ADInstruments, Inc., Dunedin, New Zealand) measured the force produced during a pull-down exercise. Prior to data collection, the force transducer was calibrated using kilogram weights.

<B>Ultrasound imaging

All images were taken with the ultrasound transducer placed over the lateral aspect of the anterior acromion, at the level of the greater tuberosity, orientated in the scapular plane perpendicular to the skin [4]. All measures were taken from static views of the subacromial space stored using the freeze facility of the scanner. The acromio-humeral distance, the smallest distance from the anterior inferior aspect of the acromion to the nearest point on the surface of the humeral head, was measured using automatic calipers software (Fig. 1).

<insert Figure 1 about here>

<B>Testing protocol

Subjects were seated, reclined to 10° from the vertical, with the arm by their side, the elbow flexed to 90° and the forearm in mid-pronation with the thumb pointing upwards. Measurements were taken sequentially with the arm at rest; with the shoulder actively elevated to 90° forward flexion, as determined using a hand-held goniometer; and during isometric pull-down of the shoulder in 90° forward flexion. The participant's height was accommodated for by adjusting the length of the pull-chain to ensure that shoulder flexion was constantly at 90° (see Fig. A, online supplementary material)

Participants familiarised themselves and warmed-up by performing pull-down exercises repeatedly with increasing force. They subsequently performed a maximal voluntary isometric contraction (MVIC) pull-down for 5 seconds, and the acromio-humeral distance and pull-down force were measured. Two further MVIC measurements were taken with a 30-second rest between measurements. Target lines at 10%, 30% and 50% of MVIC were displayed on a computer screen as feedback for the participants. Following practice and familiarisation, participants were instructed to pull-down, aiming to achieve a force at each of these three levels, three times for 5 seconds with a 30-second rest period between each pull-down. During the 5-second hold, the acromio-humeral distance was measured using the ultrasound scanner.

The protocol was repeated 1 to 3 weeks later on eight subjects (15 shoulders, three males and five females) to determine the intra-operator reliability of ultrasound measurements.

<B>Data analysis

Statistical Package for the Social Sciences Version 21 (IBM, Armonk, NY, USA) was used for all statistical analyses. Bland and Altman plots (see Appendix A, online supplementary material) and single-measure intraclass correlation coefficients ($ICC_{2,1}$) were used to compare repeated acromio-humeral distance measurements for intra-operator reliability [17]. A repeated measures analysis was performed with sex and dominant arm as factors, and force (quadratic term), age and weight as covariants. An interaction effect between sex and dominant arm was included in the model.

<A>Results

<B>Participants

Five men and 15 women (40 shoulders) with a mean age of 32 (SD 10, range 19 to 55) years, 16 right-side dominant, mean weight 65.4 (SD 11.6, range 50 to 95) kg and mean height of 168.9 (SD 9.4, range 154 to 190.5) cm volunteered for the study. Two subjects had one shoulder each that could not be imaged with sufficient clarity to be measured confidently. Therefore, a total of 38 shoulders (19 left and 19 right) were included in the analysis.

<B>Reliability

$ICC_{2,1}$ ranged from 0.764 to 0.949, suggesting almost perfect agreement [17]. Visual inspection of Bland and Altman plots indicated no systematic differences between measurements. The mean difference and levels of agreement are documented in Table 1. These data indicate excellent medium-term intra-operator repeatability.

<insert Table 1 about here>

<B>Acromio-humeral distance in different tests

Differences in the acromio-humeral distance between dominant and non-dominant shoulders are shown in Table 2. Males were found to experience a significantly greater change in the acromio-humeral distance across the observed force range compared with females. The change in the acromio-humeral distance was clinically relevant (i.e. >2 mm) for both dominant and non-dominant arms at forces of 5 to 30 kg in male subjects. In females, the mean change in the acromio-humeral distance did not reach clinical significance in the dominant arm at all levels of force. There appears to be a clinically significant change in the non-dominant arm when the force reaches 15 kg, but this may drop beneath 2 mm at a force of just under 30 kg; however, the mean change in the acromio-humeral distance did not attain clinical relevance with statistical significance at any point in females.

The limits of agreement within the reliability study suggest that, on 95% of occasions, the operator would measure within approximately 2.5 mm of the measurement obtained on the first occasion. Therefore, the error in measurement could obscure the change in the acromio-humeral distance measured.

<insert Table 2 and Fig. 2 about here>

<A>Discussion

Isometric pull-down exercises in 90° shoulder flexion were found to increase the acromio-humeral distance in pain-free participants at all levels of effort measured. However, this increase did not reach clinical relevance with statistical significance in females. Acromio-humeral measurement with ultrasound at 90° shoulder flexion was practical in most participants, and had excellent short-term intra-operator reliability.

Isometric pull-down exercises in 90° shoulder flexion have been proposed as therapeutic exercises for patients with subacromial pain syndrome as they are theorised to increase the subacromial space [11]. Subacromial pain syndrome is associated with a reduction in the acromio-humeral distance of approximately 2 mm, suggesting that this might be a clinically important change [4,7]. These findings support the clinical use of this exercise. However, as the changes were only clinically significant in male subjects and the current study only included five male subjects, this study may be underpowered to detect the significance of this change. This exercise was reviewed in an asymptomatic population, and therefore the true nature of this exercise in subjects in pain cannot be determined. It is unclear why a clinically significant change was only seen in males, but this cannot be attributed to force.

It has been hypothesised that the humeral depressing action of the latissimus dorsi, pectoralis major and teres major may contribute to the increase in the subacromial distance [10]; however, the contributions of these muscles in this role is unclear as their activity was not measured directly. The increase in distance with pull-down exercises may also be attributed to reciprocal inhibition of the deltoid muscle. Deltoid activity has been hypothesised to reduce the subacromial space [6], but the association between deltoid activity and the acromio-humeral distance has not been measured directly. Additionally, reciprocal inhibition varies according to task and region [18]. As such, mechanisms accounting for the increase in the acromio-humeral distance observed in this study must remain speculative at this point.

<B>Reliability

Real-time ultrasound measurements of the acromio-humeral distance have previously been found to be reliable when used by novice physiotherapists [16]. The present finding of excellent medium-term intra-operator reliability supports the use of real-time ultrasonography by non-specialists for measurement of the acromio-humeral distance in research and as part of the assessment and management of people with subacromial pain syndrome. However, when measuring such small clinically significant differences (2 mm), the limits of agreement within the reliability study may indicate that the changes are due to measurement error.

<B>Limitations

The main limitation of this study is that the results were derived from a pain-free population and cannot therefore be transferred directly to people with shoulder pain. Additionally, the study population was younger than the typical age for people with subacromial pain syndrome. This study may be underpowered to detect clinical change in a male population, as only five males participated.

<B>Further research

Further research is required to understand the mechanisms involved in the results seen in this study, whether the findings are also observed in a symptomatic population, and longer-term effects of pull-down exercises.

<A>Conclusion

Isometric pull-down exercises in a flexed shoulder position were shown to increase the acromio-humeral distance in asymptomatic individuals. The increase in distance was clinically relevant in male subjects at all levels of force, but did not reach clinical relevance with statistical significance in females. This exercise may benefit patients with subacromial pain syndrome. Further research is required to determine whether the same effects occur in symptomatic individuals, the mechanisms behind the observed effects, and if a rehabilitation programme incorporating this exercise has long-term effects on the acromio-humeral distance and pain and function.

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Ethical approval: Ethical approval was obtained from King's College London Research Ethics Committee (Ethics Protocol Reference No. BDM/11/12-94).

Conflict of interest: None declared.

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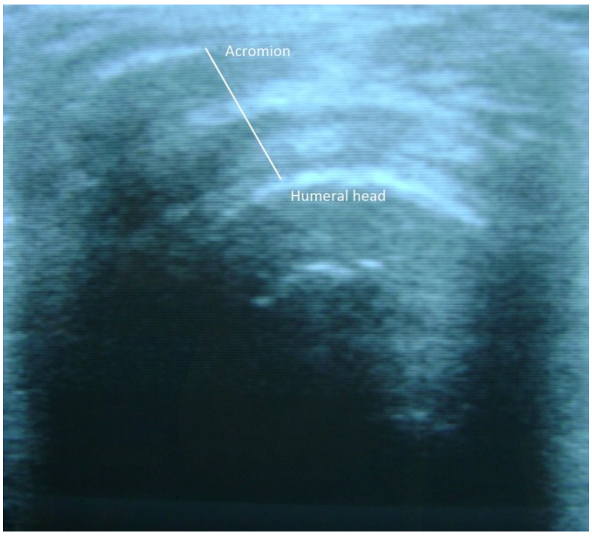

Fig. 1. Ultrasound image of the subacromial space: acromio-humeral distance measured between tip of acromion and nearest point on humeral

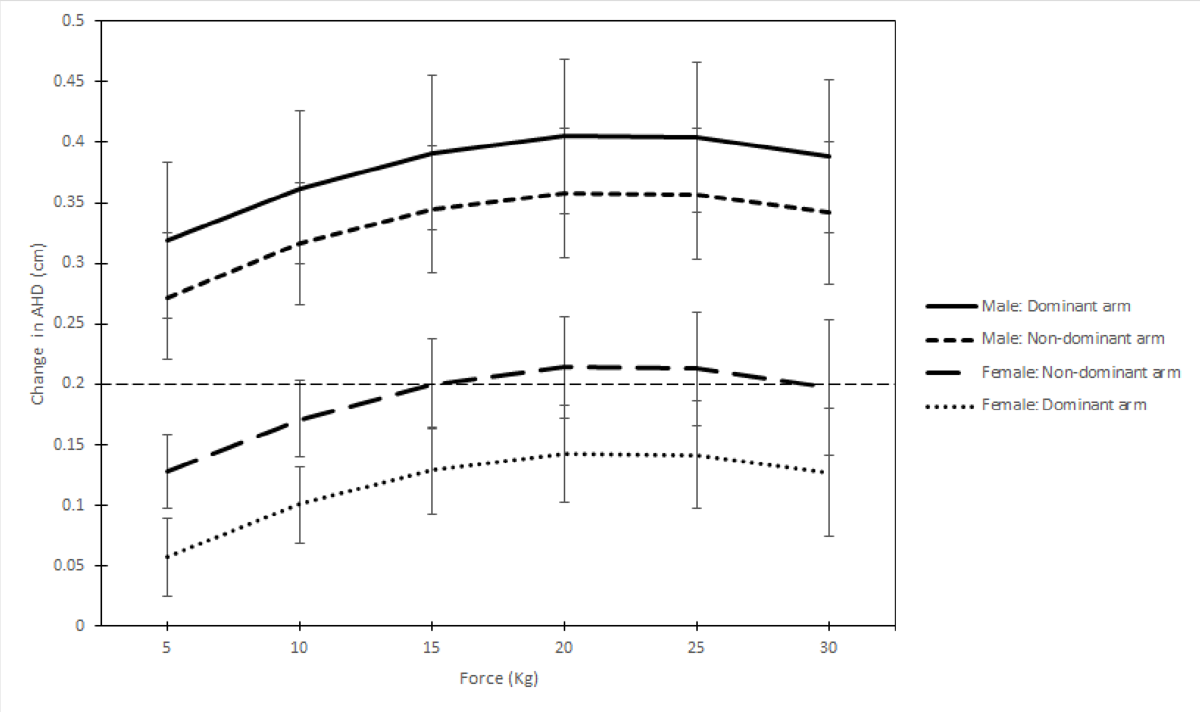

Fig. 2. Pull-down force (kg) in relation to the change in the acromio-humeral distance (AHD) (cm). The plot shows the difference between sexes and dominant/non-dominant arms, with a clinically relevant change in AHD shown within the plot. The results show that male subjects reach clinically relevant changes in AHD with all levels of force. Females reach clinically relevant changes at forces of 15–30 kg; however, this does not reach statistical significance.

Table 1

Intraclass correlation coefficients (ICC), 95% confidence intervals (CI), mean of differences between the two measures and 95% limits of agreement

	ICC		Bland-Altman	
	ICC coefficient	95% CI	Mean of differences (mm)	95% limits of agreement (mm)
No pull-down, 90° flexion	0.764	0.610 to 0.863	0.04	-2.37 to 2.45
10% MVIC, 90° flexion	0.927	0.871 to 0.959	-0.20	-2.03 to 1.63
30% MVIC, 90° flexion	0.880	0.793 to 0.932	0.38	-1.85 to 2.61
50% MVIC, 90° flexion	0.910	0.842 to 0.949	0.17	-1.94 to 2.28
100% MVIC, 90° flexion	0.793	0.654 to 0.881	-0.25	-3.11 to 2.61
At rest, in neutral	0.949	0.909 to 0.971	0.08	-1.35 to 1.50

MVIC, maximal voluntary isometric contraction.

This table shows the results of the reliability study undertaken in eight subjects with 1 to 3 weeks between testing protocols.

Table 2
Acromio-humeral distance at different shoulder positions and force of pull-down exercise

Position	Mean (SD) (mm)	Mean (SD) change (mm)	*P*
No pull-down, 90° flexion	**8.8 (1.9)** *8.3 (1.8)*		<0.001
10% MVIC, 90° flexion	**9.0 (3.0)** *9.2 (2.4)*	**1.1 (2.5)** *0.9 (2.0)*	<0.001
30% MVIC, 90° flexion	**9.9 (2.9)** *9.8 (2.3)*	**1.2 (2.4)** *1.5 (2.2)*	<0.001
50% MVIC, 90° flexion	**10.3 (3.0)** *10.6 (2.0)*	**1.5 (2.5)** *2.3 (2.1)*	<0.001
100% MVIC, 90° flexion	**10.2 (2.7)** *11.2 (1.8)*	**1.5 (2.2)** *2.9 (2.0)*	<0.001
At rest, in neutral	**11.8 (2.2)** *11.3 (2.3)*	**3.0 (2.3)** *3.0 (2.5)*	<0.001

MVIC, maximal voluntary isometric contraction; SD, standard deviation.

Bold text represents the dominant arm, and italic text represent the non-dominant arm